Marine Research

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Marine Research
1960 No. 1

The Herring of the Clyde Estuary

By HENRY WOOD, M.A., Ph.D., F.R.S.E.

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Marine Laboratory, Aberdeen

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The Herring of the Clyde Estuary

INTRODUCTION

The earliest record of herring as an article of commerce in Scotland appears in a charter granted in 1138 by King David I to the Abbey of Holyrood which, amongst other endowments granted to the Abbey the right to fish herring at Renfrew (Mitchell 1864).

At about this time the Scottish herring fisheries were confined to the firths and estuaries and in 1429 great quantities of herring were caught at the mouths of the Dee, Tay, Forth, Tweed, etc., while Loch Fyne "had been anciently known as a fishing station" (*ibid.*). The implications are that the Clyde herring fisheries are as ancient as any in Scotland.

In the latter half of the 17th century there was some trade in salt herring between the Clyde and France and in 1674, 20,400 barrels were exported to La Rochelle (Jenkins 1927). A considerable trade was also developed in the West Indies, and in 1709 the export to this market from Clyde ports amounted to 40,000 barrels.

During the 17th century, according to Jenkins, when much unavailing effort was being made by the Stuart kings to develop an open sea herring fishery on the same lines as that of the Dutch, a considerable inshore fishery was carried on in Loch Fyne and the Firth of Clyde by inhabitants of Glasgow, Dumbarton and Ayrshire. The boats were small, each being manned by 4 men and equipped with 24 nets and as many as 900 frequently took part in the fishery between 25th July and Christmas.

Mitchell records that in December 1835 Loch Fyne was visited by a most extraordinary shoal of herrings. They made their appearance in some bays in such prodigious quantities that the usual method of fishing was departed from, and nets of every description were stretched across the bays and enclosed all the fish until the receding tide, when they were left high and dry upon the beach: two boats engaged in this fishing each caught from 20 to 25 maizes (500 to the maize) each night.

One is tempted to believe that the experimentation in 1835 led to the introduction of the ring net in 1838.

METHODS OF FISHING

Drift Net

Until the introduction of the ring net, herring fishing in the Clyde had been carried on mainly by drift net, although so-called "trammels" were also used near the Ayrshire Coast and particularly on Ballantrae Bank.

It soon became clear that the ring net and drift net methods of fishing could not be carried on simultaneously on the same grounds and clashes between fishermen using these two methods became frequent. The drift net men, supported by curers and others, alleged that the ring net was a destructive method of fishing in that sometimes it caught large numbers of small immature herring. This view prevailed and an Act prohibiting the use of the ring net was passed in 1851 (Fulton 1900).

In spite of restrictions the ring net had established itself as a very effective method of fishing in sea lochs and estuarine waters, and in 1867 on the recommendation of the Playfair Commission (1863) an Act was passed to amend the Acts relating to the British White Herring Fishing and the restrictions in the use of the ring net were finally removed.

In 1862 when the prohibitions against the use of the ring net were rigidly enforced, the Loch Fyne herring fleet consisted of 772 drift net vessels; there were no ring net vessels. With the removal of the restrictions in the use of the ring net in 1867 this method of fishing quickly returned to favour and in

the years 1893 and 1899, according to Fulton (1900), the following drift and ring net vessels engaged in the herring fishery from Loch Fyne, Campbeltown and Ayrshire:—

Year	Drift Net	Ring Net
1893	720	644
1899	604	606

Thus at the close of the 19th century the vessels engaging in fishing solely by drift net or by ring net were about equal in numbers.

At Rothesay between 1902 and 1909 the drift net fleet ranged from 18 to 100 vessels while ring net vessels varied from 120 to 300. The continuing decline in the number of drift net vessels at Rothesay may be judged by the following landings in crans by the two methods of fishing at that port between 1910 and 1913:—

Year	Drift Net	Ring Net
1910	939	13,272
1911	481	7,271
1912	78	4,517
1913	274	3,783

The introduction of motor propulsion for fishing craft at Campbeltown in 1907, in giving greater manoeuvrability to vessels in narrow waters, undoubtedly proved a greater asset to the ring net vessels than to the drifters and contributed to the further development of the ring net fishery.

By the outbreak of the first world war fishing by drift net was no longer important in the Clyde although a few drift net vessels, mainly from ports outside the Clyde, continued to make visits to the Clyde herring grounds until about 1930 or 1931. Since that time this method of fishing has not been practised to any appreciable extent.

Ring Net

According to Holdsworth (1883) the ring net, in its original form, consisted of two drift nets laced together; although there is some variation in the dimensions to suit shallow or deep water, the usual measurements of the net when mounted are 200 yd long by 40 yd deep. There is no pocket or cod-end but the yarn is "gathered" from 300 yd to 200 yd on the ropes to make a deep belly when the net is being hauled. The meshes differ in size in different parts of the net and range from 20 rows per yd in the wings to about 40 rows in the upper bag or basketing sling. See Figure 1.

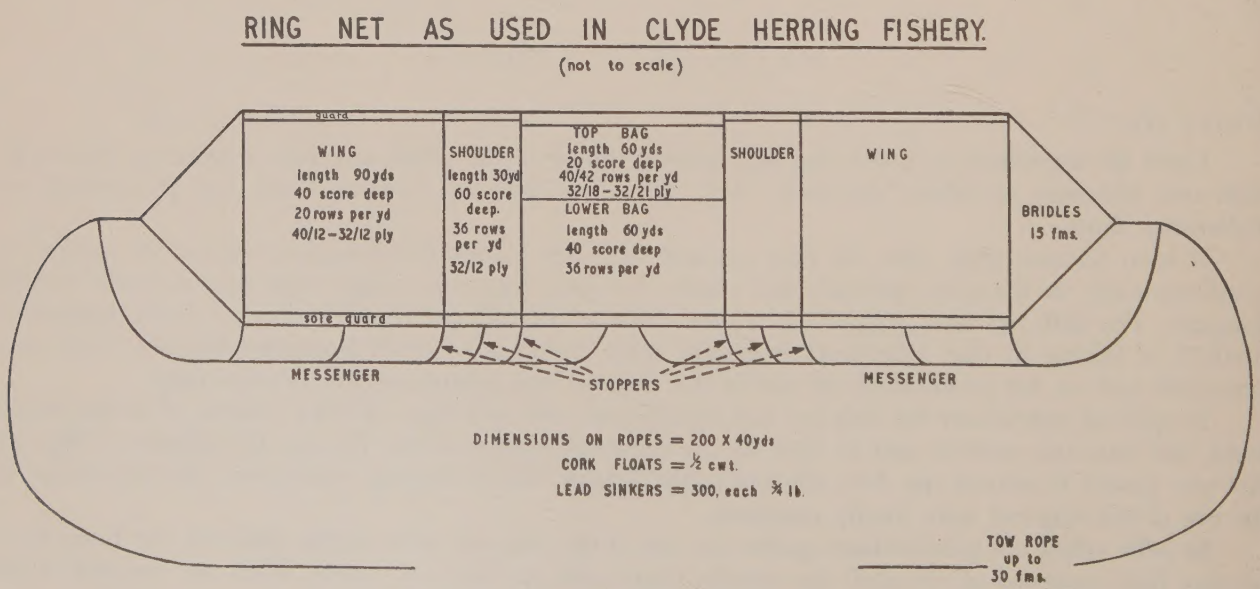

Fig. 1

Originally the success of the ring net depended largely on the skill of the fishermen in locating a shoal, and Clyde fishermen became expert in recognising the signs associated with the presence of herring.

In 1931 Clyde fishermen adopted the "feeling wire" as a means for the location of herring shoals. The "feeling wire," which had been developed in Scandinavian countries and was first tried in the Clyde in 1925, consisted of a length of copper wire to which a lead weight of about 6 lb was attached. In a search for herring the weight was towed slowly through the water and the holder of the taut wire was able to feel the taps on it as it was struck by passing fish. A skilful fisherman could give a fair estimate of the density of a shoal by the number of taps recorded on the wire.

The "feeling wire" was a simple but reasonably effective means of locating a herring shoal especially in winter when the water was not highly phosphorescent. It was, however, superseded in the United Kingdom by the echo-sounder which was adopted generally throughout the main British fisheries on the completion of the second World War.

Ring net vessels operate in pairs, each with its net at the stern ready for shooting. Each carries out a search at hailing or easy signalling distance from the other. Whenever a boat locates a shoal it commences shooting its net in an arc round the position of the shoal. The companion boat joins the operation by picking up the outer end of the net. Whenever shooting is completed, the two vessels steam on converging courses, thereby contracting the arc of the net to a complete circle. When the two vessels meet, usually within five minutes, the crew of one, except for a single member, crosses over to the other vessel on to which the net is to be hauled. Hauling operations now begin by hauling in the footrope on to the boat from which it was shot, and when this is completed the shoal is enclosed on all sides. Meantime the other boat with only its skipper or a single member of its crew on board tows the hauling boat off the net with the intention of keeping the catch in the belly of the net and holding the gear taut, thereby ensuring a clean and orderly haul. When the catch is finally concentrated in the upper bag of the net the companion boat ceases towing and takes up position alongside the other. The upper bag or upper middle of the net is then suspended between the two boats and the catch is quickly baled out by means of a brailer.

The ring net boat measures generally from 50 to 55 ft in length and is propelled by a diesel engine; each carries a crew of 5, including the skipper.

Trammel

The "trammel" is in fact a ground or set net, the dimensions of which are 27 fathoms long by $2\frac{1}{2}$ fathoms (5 score) deep. The meshes measure 32 to 34 rows to the yard. The nets are shot usually in small fleets; today a fleet normally consists of 10 nets. They are untanned, alum being used as a preservative. At the present time, they are used almost exclusively on Ballantrae Bank between the end of January and the end of March, when ripe herring normally assemble on the bank to spawn.

FISHING GROUNDS

During summer, autumn, and part of the winter, fishing for herring may take place anywhere within the Firth north of the south coast of Arran, but the grounds most frequented are Kilbrennan Sound, Inchmarnoch Water and Lower Loch Fyne. In late autumn, more especially when herring in their second year (halflins) are abundant in the catches, a good deal of fishing frequently takes place in Loch Striven, and the adjacent Loch Riddon, and sometimes further within the estuary in Loch Long and Gareloch. Towards the end of the year there is frequently a concentration of fishing effort in Kilbrennan Sound and lower Loch Fyne. In February and March shoals of ripe herring converge near the south coast of Arran and on Ballantrae Bank, where the sea floor consists of gravel and is eminently suitable for the lodgement of herring spawn. At this period the shoals which concentrate on Ballantrae Bank are exploited by trammel net fishermen from Girvan and if the weather is suitable ring net fishermen frequently operate along the south coast of Arran.

While the herring from the bank and South Arran in February and March consist almost entirely

of ripe spawning fish, the catches from the estuary are frequently very mixed and may include fish at all stages of maturity, from immature adolescents to ripe adults. It would appear appropriate, therefore, to sub-divide the estuary into the outer estuary, extending outwards from the south coast of Arran where fishing is important only during the spawning season i.e. February-March, and where the shoals consist exclusively of spawning adults, and the inner estuary where fishing is or may be carried on throughout the year, and where the maturity composition of the shoals is extremely variable.

PREVIOUS WORK ON THE CLYDE HERRING

Cossar Ewart (1884) confirmed Ballantrae Bank as a spawning ground for spring spawning herring by dredging herring spawn from the bank in March and April 1883. He expressed the view that after spawning, the herring leave the coast and he saw no reason to believe that the herring which spawn on Ballantrae Bank frequent Loch Fyne.

George Brook (1886) was of the opinion that the herring of Loch Fyne included more than one type. Herring resorted to Loch Fyne to feed but the majority left the loch before the spawning season. His view was that Loch Fyne may be a feeding ground for the herring which spawn on Ballantrae Bank. Brook maintained that besides the spring spawning on Ballantrae Bank there was a spawning in October at the head of Loch Fyne, but that this spawning ground had declined greatly in importance. He maintained that there was still some spawning in the lower portion of Loch Fyne but there was no regular spawning ground as at Ballantrae. Brook and Calderwood in August 1885 went to sea three or four nights a week to collect ripe herring for fertilization experiments but for some considerable time failed to secure both ripe males and females on the same evening, and although suitable material was finally obtained on 11th September it was obvious from their experience that ripe autumn spawning herring were not numerous in the area.

Fulton (1900), in an inquiry on the action of the herring seine net, has given a detailed account of the history of the ring net since its introduction in 1838. He found that the ring net was more destructive of young fish than either drift or trammel nets but that there was no evidence that its action was injurious to the permanence of the supply of herring in Loch Fyne. While he was aware that Loch Fyne fishermen regarded Ballantrae Bank as a spawning ground for the Loch Fyne herring, he could not find conclusive evidence to support this view.

Williamson (1909) made a large number of measurements of ovaries and ova from Clyde herring and he came to the conclusion that while the majority of the Clyde herring were spring spawning, a considerable proportion were autumn spawners. Although his records showed a number of herring with well developing gonads in the later months of the year, one cannot but note the scarcity of ripe or spent herring in his autumn samples.

Finally, Marshall, Nicholls and Orr (1939) caught in 1935, 1936 and 1937, considerable numbers of O group herring which they were able to demonstrate by counts of the vertebrae to include progenies from both spring and autumn spawnings. They failed, however, to obtain evidence of spawning in autumn, either in the condition of the gonads of adult fish or in the occurrence of autumn produced larvae, and they came to the conclusion that autumn produced progeny, of the O group, took their origin from the autumn spawners of the Isle of Man grounds.

The evidence collected so far would appear to indicate that the Clyde stock of herring is of mixed composition.

The most important component of the commercial catches is the immature stages beyond the O group stage and it is the purpose of this paper to investigate the relationship of this group with the adults which spawn on Ballantrae Bank and its neighbourhood in February and March, or with any group of adults which contribute to the Clyde stock of herring.

MATERIALS AND METHODS

After considerable exploratory investigation it was realised about the year 1930 that the herring population in Scottish waters was composite and that elucidation of the herring problem would depend largely on the identification of the various herring types which maintained the various fisheries. The herring of the Clyde estuary were included in the programme of research and this paper is based on that part of the work carried out between 1930 and 1939. The material included 82 quarter-cran samples caught by ring net and 18 samples caught by "trammel." Samples, which were representative of the

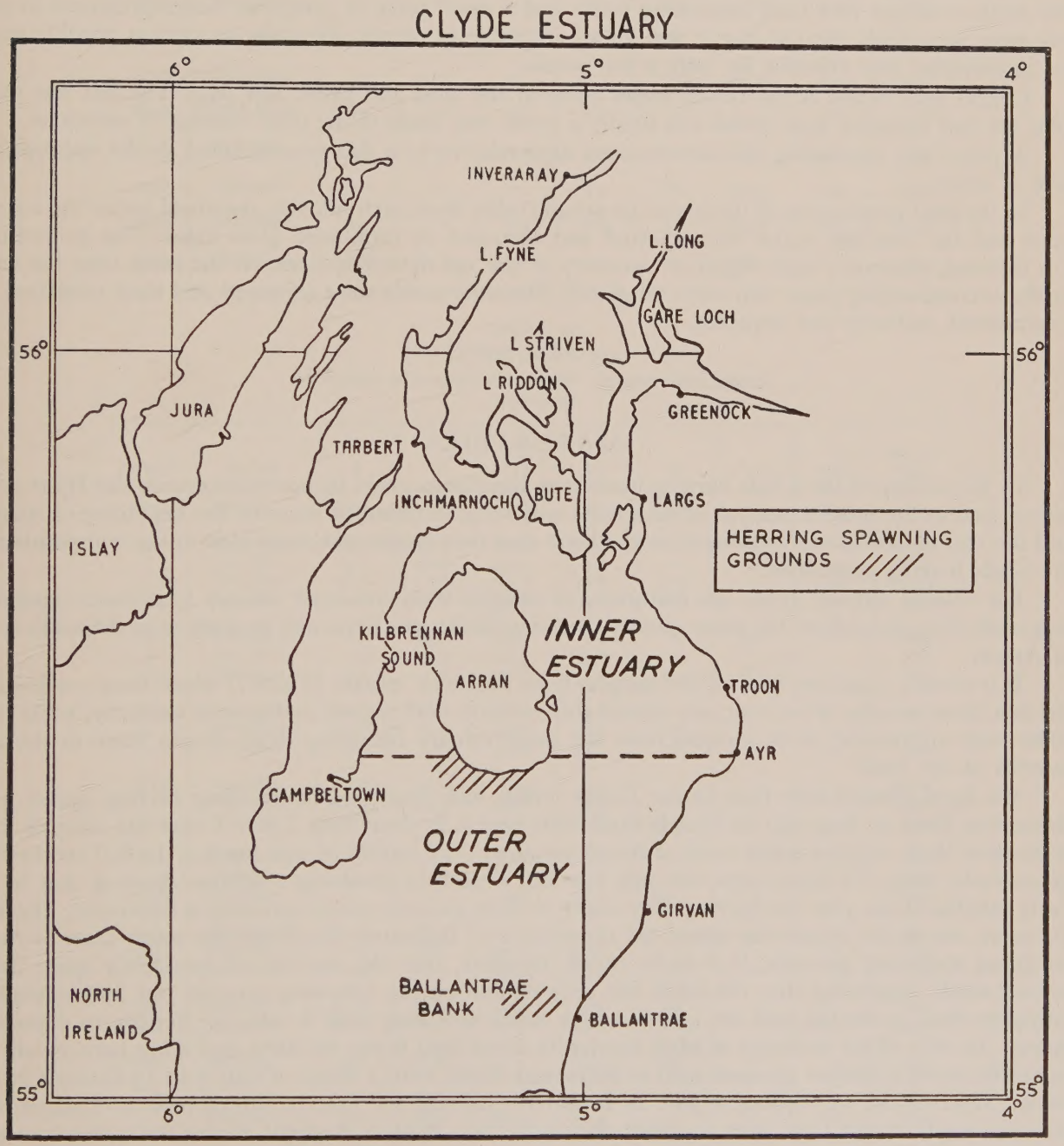

Fig. 2

general landings and rarely contained less than 250 fish, were despatched to the Marine Laboratory by the District Fishery Officers.

During summer some samples arrived in rather poor condition and while it is believed that deficiencies in data arising from deterioration during transport were not serious, it is probable that some error in the counts of keeled scales could arise.

The following routine was followed in the examination of the material.

Fish were measured from the tip of the snout to the end of the ventral lobe of the tail fin, brought into line with the mid line of the body.

A large sample of scales was taken from the flank between the line of the dorsal fin and the head. The scales were put in a tube containing water and a small piece of camphor. Scales preserved in this way were very easily cleaned but it was found advisable to mount the scales as soon as possible since the preservative was effective for only a few weeks.

Counts were made of the keeled scales between the anus and pelvic fins (K_2). The fish was then split, sex and maturity were noted and finally a count was made of the total number of vertebrae.

A paper slip containing all measurement data relative to a fish was included in the appropriate tube of scales.

In the final preparation of the scales the sample taken from each fish was examined under the microscope and the two best scales were selected and mounted on numbered glass slides. This procedure, it is believed, ensured a high degree of accuracy in the age determinations. At the same time the data on the accompanying paper slip were tabulated. Mounted scales were arranged and data tabulated in a numbered maturity size sequence.

MATURITIES

In this survey of the Clyde herring maturities have been given in accordance with the Hjort scale (1910), and in the present analysis of maturities only samples obtained between the beginning of August and the end of March are considered in the hope that they might give some clue to the composition of the Clyde herring population.

For reasons already given the maturities of samples from the inner estuary have been tabulated separately from those from the outer estuary, i.e. from Ballantrae Bank and grounds near the south coast of Arran.

It is at once apparent that all the samples from the outer estuary (Table I) which were confined to the first three months of the year, are remarkably uniform with regard to degree of maturity, while they differ very appreciably from samples from the inner estuary including those caught there in the first months of the year.

We have already seen that Cossar Ewart (1884) had succeeded in dredging herring spawn from Ballantrae Bank as long ago as March-April 1883 and it is clear from Table I that the samples from Ballantrae Bank and the south coast of Arran consisted very largely of ripe herring. In fact the herring given under stage VI (ripe) were not only ripe but were in a spawning condition showing that in the early months of the year the herring only resort to these grounds when spawning is imminent. There is, therefore, no doubt whatsoever about the importance of Ballantrae Bank and the south coast of Arran as spring spawning grounds. It is to be noted, however, that the number of completely spent fish is always small, suggesting that the adult fish only remain on the spawning grounds just long enough to complete their spawning and the question now arises how long does it take the herring to deposit its spawn. In view of the tendency of adult herring to avoid light it can be taken that adult herring will not normally occupy shallow grounds such as Ballantrae Bank, with a depth of only 7 to 13 fathoms, before dusk. Nevertheless, my colleague Mr. B. B. Parrish informs me that recent surveys have shown that numerous echo-traces have been recorded over Ballantrae Bank in daylight during the spring spawning season; he adds, however, that the water was quite turbid at the time. It would appear, therefore, that

TABLE I
CLYDE HERRING
Maturities of Samples from Outer Estuary (Percentages)
1930-1939

Year	Period	I	II	III	IV	V	VI	VII	No. of Fish
1930	February	—	—	—	1·8	17·3	77·2	3·6	221
1931	Feb.-Mar.	—	—	0·2	1·8	2·2	93·4	2·4	697
1932	Feb.-Mar.	—	—	—	0·7	2·1	96·8	0·4	565
1933	Feb.-Mar.	—	—	0·4	2·5	6·6	88·9	1·5	823
1934	Feb.-Mar.	—	0·1	4·1	24·3	7·8	62·1	1·7	1207
1935	Feb.-Mar.	—	—	0·5	2·2	3·0	94·1	0·2	798
1936	Feb.-Mar.	0·2	0·2	0·3	5·2	10·0	83·6	0·5	799
1937	February	—	—	—	4·3	6·0	89·3	0·4	501
1938	Feb.-Mar.	0·4	—	0·3	0·6	4·2	94·0	0·6	1117
1939	March	1·6	0·3	—	0·1	0·1	96·1	1·7	770

TABLE II
CLYDE HERRING
Maturities of Samples from Inner Estuary (Percentages)
1930-1939

Year	Period	I	II	III	IV	V	VI	VII	No. of Fish
1930	March	62·9	19·8	11·6	3·1	—	0·3	2·3	793
1930	Aug.-Sep.	71·7	16·9	10·6	0·8	—	—	—	3493
,,	Oct.-Nov.	23·7	28·7	43·4	4·2	—	—	—	1680
,,/31	Dec.-Jan.	28·0	17·6	39·0	14·8	0·5	—	0·2	1026
1931	January	2·6	5·4	31·6	58·1	2·3	—	—	430
1931	Aug.-Sep.	71·0	14·7	13·0	1·2	—	0·1	—	1886
,,	Oct.-Nov.	9·3	41·7	44·9	4·0	—	—	—	833
1932	February	9·4	1·3	23·6	57·0	8·4	0·3	—	381
1932	September	21·1	50·1	26·6	2·2	—	—	—	327
,,	November	11·2	3·2	44·7	38·2	2·6	—	—	311
,,	Oct.-Nov.	7·6	9·0	55·4	26·7	1·3	—	—	590
1933	Aug.-Sep.	69·8	20·5	9·3	0·3	—	—	0·1	1722
,,	November	27·3	13·4	49·8	9·4	—	—	—	498
1934	January	2·1	5·8	54·8	36·0	1·3	—	—	377
1934	September	5·7	79·4	14·5	0·4	—	—	—	282
,,	October	3·5	19·7	65·8	11·0	—	—	—	289
1935	February	—	—	9·0	63·1	20·2	7·7	—	233
1935	September	42·3	38·2	16·0	3·6	—	—	—	364
1936	January	11·9	6·6	32·3	49·2	—	—	—	303
,,	February	0·9	0·9	43·7	51·0	3·0	0·6	—	334
1936	August	33·2	52·0	13·3	1·5	—	—	—	262
1937	January	21·1	11·6	17·7	45·8	3·1	—	0·7	293
1938	January	6·4	12·9	41·4	36·4	3·0	—	—	284
1938	August	10·1	56·6	31·8	1·5	—	—	—	267
,,	October	5·7	18·8	62·1	13·4	—	—	—	261
1939	November	24·8	12·8	38·5	22·0	1·7	—	0·2	510

spawning may take place on Ballantrae Bank during daylight. Catches from the bank are nearly always in a partially spent condition; the number of completely spent fish is always quite small. The implications are that the fish desert the bank whenever spawning is completed and that the spawning act of the individual fish is not a protracted process. Holliday (1958), who succeeded in catching some ripe herring on Ballantrae Bank and was able to study their spawning behaviour in a tank, found that spawning was interrupted when all light was excluded, and from the observed rate of spawning he came to the conclusion that the spawning act is completed by the individual fish within two to four hours. So far no evidence has been found in conflict with this conclusion.

It will be seen that the population of the inner firth as represented in Table II consists of a mixture of immature and maturing fish, and both in the autumn and the spring the number of fish classified as ripe is almost insignificant and none so far has been found in a spawning condition. (It is remembered, however, that Calderwood and Brook did succeed in September 1885, after considerable search and effort, in obtaining a few ripe herring which were successfully used in fertilization experiments) Analysis of maturities of the herring from the inner estuary, while making it quite evident that very little spawning takes place inside the Clyde estuary either in spring or autumn, helps little in the identification of the herring type or types which frequent the estuary and which are the mainstay of the Clyde herring fishery. Fortunately counts were made of vertebrae and keeled scales (K_2) in a number of samples and these reveal the true identity of the estuarine herring.

RACE ANALYSIS OF ADULT HERRING

The starting point in Scottish "race" investigations has been to determine first the "race" characteristics of the major spawning groups and to use these as standards for the identification of herring, caught between seasons, whose spawning times may not be readily established by the condition of the gonads. Characters used have been maturity and counts of vertebrae (Vert. S.) and the number of keeled scales between the pelvic fins and the anus (K_2).

All observations were made by the same team of three workers and accordingly it is considered that any personal error involved should be fairly consistent throughout.

The following are the total vertebrae and keeled scales (K_2) of spawning or newly spent herring caught in February and March near the south coast of Arran or on Ballantrae Bank. These are followed by corresponding data from fish which had spawned in the region of the Isle of Man in autumn, or which, judged by the condition of the gonads, were maturing to spawn in that season.

Counts of Vertebrae and Keeled Scales (K_2)
Spring Spawners: Outer Estuary of Clyde 1931-1939
Maturity Stages VI (Majority) and VII

Feb.-March 1931				February 1934			
Vert. S.		K_2.		Vert. S.		K_2.	
59	1	17	1	59	3	16	9
58	120	16	11	58	96	15	102
57	376	15	198	57	213	14	176
56	99	14	296	56	36	13	61
55	1	13	83	—	—	12	1
54	1	12	5	—	—	11	1
	598 Mean=57·03		594 Mean=14·22		348 Mean=57·19		350 Mean=14·16

Counts of Vertebrae and Keeled Scales (K_2)

Spring Spawners: Outer Estuary of Clyde 1931-1939

Maturity Stages VI (Majority) and VII

March 1935

Vert. S.		K_2.	
59	4	16	1
58	78	15	62
57	130	14	140
56	34	13	36
—	—	12	3
	246 Mean=57·21		242 Mean=14·09

February 1937

Vert. S.		K_2.	
59	2	17	2
58	122	16	17
57	326	15	139
56	48	14	271
55	2	13	61
54	1	12	2
	501 Mean=57·14		492 Mean=14·23

Feb.-March 1936

Vert. S.		K_2.	
59	6	16	11
58	132	15	131
57	301	14	260
56	57	13	85
55	2	12	2
—	—	11	1
	498 Mean=57·14		490 Mean=14·12

Feb.-March 1938

Vert. S.		K_2.	
59	3	16	13
58	117	15	171
57	356	14	267
56	70	13	83
—	—	12	4
	546 Mean=57·10		538 Mean=14·20

March 1939

Vert. S.		K_2.	
58	75	16	10
57	363	15	180
56	84	14	261
55	1	13	64
—	—	12	4
	523 Mean=56·98		519 Mean=14·25

Autumn Spawners: Near Cumberland Coast

Maturity Stage VII (Spents)

November 19th, 1936

Vert. S.		K_2.	
58	8	18	1
57	92	17	3
56	92	16	24
55	6	15	91
—	—	14	71
—	—	13	7
	198 Mean=56·52		197 Mean=14·74

Autumn Spawners: Isle of Man

Maturity Stages V (Majority) & VI

August-September 1937

Vert. S.		K_2.	
58	4	17	1
57	102	16	30
56	148	15	121
55	13	14	95
—	—	13	18
—	—	12	1
	267 Mean=56·36		266 Mean=14·61

The spring spawners of the Clyde estuary have the "race" characters typical of the spring spawners of the N.E. Atlantic, which are characterised by a high number of vertebrae and a low number of keeled scales (K_2). The mean vertebral count ranges from 56·98 to 57·21, and the mean K_2 from 14·09 to 14·25. On the other hand the corresponding figures for autumn spawners from the Isle of Man and from the Cumberland coast are for vertebrae 56·36 and 56·52 and for K_2 14·61 and 14·74.

Tåning (1944) experimenting with trout and Blaxter (1957) experimenting with herring have established that the number of vertebrae is affected by the temperatures to which the ova are subjected during the early stages of their development after being spawned. Nevertheless there is an interval of about six months between the spring and autumn herring spawning seasons which is associated with distinct differences in the spawning temperatures (5°-6° and 10°-11°C). Temperature variations at the two spawning seasons are most unlikely to reach a magnitude that would obliterate the differences in the counts of vertebrae and keeled scales. There has been no evidence of change from one spawning time to another and so the physiological and anatomical differences in the two major herring types in the Scottish area persist and are likely to persist, as long as the present seasonal differences in temperatures are maintained.

HERRING OF THE INNER ESTUARY

Race Analysis of Immature Herring

Table II shows that the herring of the inner estuary are a mixture of immature and maturing fish. The number of fish classified as ripe or spent is quite insignificant during either the spring or autumn spawning seasons, indicating that the number of fish which spawn within the estuary is quite small. Maturity by itself, however, helps little in the identification of the mixed shoals which frequent the inner firth, but counts made of vertebrae and keeled scales (K_2) provide some clue as to the identity of the fish.

The following data pertain to sexually undeveloped fish (Maturities I and II) caught within the estuary.

Herring of the Inner Estuary of Clyde

Maturity Stages I and II

Loch Fyne, August 11th, 1931

Vert.	S.	K_2	
59	3	16	—
58	17	15	19
57	41	14	43
56	8	13	8
	69 Mean=57·23		70 Mean=14·13

Off Ardrossan, Sept. 5th, 1934

Vert.	S.	K_2	
59	—	16	1
58	11	15	9
57	23	14	18
56	4	13	8
55	—	12	2
	38 Mean=57·18		38 Mean=13·97

Between Arran and Inchmarnoch, Sept. 5th, 1935

Vert.	S.	K_2	
59	2	16	10
58	70	15	79
57	175	14	173
56	42	13	24
55	—	12	2
	289 Mean=57·11		288 Mean=14·25

Loch Long, January 21st, 1936

Vert.	S.	K_2	
59	—	16	1
58	9	15	19
57	41	14	25
56	4	13	10
55	1	12	1
	55 Mean=57·05		56 Mean=14·16

Herring of the Inner Estuary of Clyde

Maturity Stages I and II

Kilbrennan Sound, July 15th, 1936

Vert. S.		K_2.	
59	1	16	7
58	42	15	59
57	121	14	99
56	28	13	23
55	—	12	2
	192 Mean=57·08		190 Mean=14·24

Kilbrennan Sound, January 19th, 1937

Vert. S.		K_2.	
58	8	16	6
57	56	15	31
56	31	14	38
55	1	13	16
	96 Mean=56·74		91 Mean=14·30

Loch Fyne, January 26th, 1938

Vert. S.		K_2.	
58	5	16	3
57	36	15	20
56	9	14	21
55	1	13	7
	51 Mean=56·88		51 Mean=14·37

Kilbrennan Sound, August 2nd, 1938

Vert. S.		K_2.	
59	—	16	5
58	25	15	51
57	113	14	95
56	37	13	25
55	2	12	2
	177 Mean=56·91		178 Mean=14·18

Loch Fyne, October 18th, 1938

Vert. S.		K_2.	
59	—	16	2
58	13	15	21
57	34	14	31
56	17	13	9
	64 Mean=56·94		63 Mean=14·25

The above records show that the samples of immature herring examined between 1931 and 1936 have the characters typical of spring spawning fish. The material collected in 1937 and 1938 diverges slightly from the general pattern; the slight lowering in the counts of vertebrae and increase in the number of K_2 in these years imply a small admixture of fish of the autumn spawning type.

Race Analysis of Maturing Herring

The following are the counts of Vert. S. and K_2. of the maturing components of Clyde samples caught between July and January. The number of maturing herring in some samples is quite small but they had been included although it is recognised that it would be unwise to base firm conclusions on them.

Herring of the Inner Estuary

Maturity Stages III and IV

Off Ardrossan, September 5th, 1934

	Vert. S.		K_2.
59	—	16	1
58	8	15	6
57	15	14	13
56	3	13	5
	26 Mean=57·19		25 Mean=14·12

Between Arran and Inchmarnoch, Sept. 5th, 1935

	Vert. S.		K_2.
59	—	16	7
58	11	15	31
57	42	14	28
56	18	13	5
	71 Mean=56·90		71 Mean=14·56

Loch Long, January 21st, 1936

	Vert. S.		K_2.
59	3	16	6
58	50	15	65
57	167	14	135
56	25	13	36
55	—	12	1
—	—	11	1
	245 Mean=57·12		244 Mean=14·15

Kilbrennan Sound, July 15th, 1936

	Vert. S.		K_2.
59	—	16	2
58	1	15	5
57	4	14	1
56	4	13	1
	9 Mean=56·67		9 Mean=14·9

Kilbrennan Sound, January 19th, 1937

	Vert. S.		K_2.
59	—	17	1
58	49	16	4
57	121	15	56
56	24	14	97
—	—	13	35
—	—	12	1
	194 Mean=57·13		194 Mean=14·15

Kilbrennan Sound, August 2nd, 1938

	Vert. S.		K_2.
59	—	17	1
58	12	16	3
57	59	15	26
56	15	14	48
55	3	13	10
	89 Mean=56·90		88 Mean=14·28

Loch Fyne, October 18th, 1938

	Vert. S.		K_2.
59	—	16	6
58	28	15	67
57	135	14	96
56	33	13	25
55	1	12	1
	197 Mean=56·96		195 Mean=14·23

Only the fourth sample in the above series, i.e. that caught on July 15th 1936, consisting of 9 fish out of a total of 201 in the original sample, might be accepted as herring belonging to an autumn spawning type. The relatively high K_2 associated with a slight lowering in the number of vertebrae in the sample caught between Arran and Inchmarnoch on September 5th, 1935, suggests that the sample included some autumn spawners. It is quite clear, however, that both the immature and maturing herring caught in the Clyde during the autumn and early winter belong very predominantly to a spring spawning type.

Although the records of Marshall, Nicholls & Orr make it clear that autumn spawning herring of the O group may occur in considerable numbers in the Clyde estuary, as in 1936, older stages of the autumn spawning type were at no time conspicuous in samples examined between 1930 and 1939. The scarcity of ripe or spent fish in autumn suggests that the autumn spawners leave the estuary before the adult stage is reached. Whether that is indeed the case or not there can be no doubt whatsoever that the samples of commercial catches at all seasons consisted predominantly and sometimes almost exclusively of spring spawning fish.

AGE ANALYSIS OF THE CLYDE HERRING

Although herring of the autumn spawning type occur at the O group stage in the Clyde estuary, analyses of maturities and counts of vertebrae and K_2 show that herring of the autumn spawning type have been inconspicuous in the samples of commercial catches examined between 1930 and 1939. It is proposed, therefore, for the sake of simplicity to ignore the unimportant autumn spawning component in the analysis of age composition and to regard the commercial samples as consisting of spring spawning herring.

Table III gives the percentage contributions by the various year classes to the Clyde commercial catches from May to December between 1930 and 1939.

TABLE III

AGE COMPOSITION OF COMMERCIAL CATCHES
CLYDE ESTUARY—MAY TO DECEMBER, 1930-1939 (Percentages)

Year of Capture	Year Classes										
	1924-27	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
1930	6·6	*92·4*	1·1								
1931	1·8	*75·4*	22·0	0·8							
1932	0·6	*69·0*	10·9	15·7	*3·8*						
1933	0·0	*1·7*	0·5	4·2	*93·1*	0·4					
1934	0·2	*1·3*	0·7	3·6	*86·5*	6·8	*0·9*				
1935					0·6	0·4	*98·8*	0·3			
1936					0·8	0·5	*65·9*	11·1	*21·8*		
1937						0·0	0·4	0·0	*99·6*		
1938							0·2	2·7	*94·8*	0·7	1·5
1939									*22·0*	0·6	*77·4*

From 1930 to 1939 there were five outstanding year classes 1928, 1931, 1933, 1935 and 1937, and it was possible to keep in touch with all, except the last mentioned, for several years. The 1928 year class, which was one of the most abundant broods that has come under the writer's observation, appeared for the first time in the commercial catches towards the close of 1929 and dominated the

estuarine catches throughout 1930, 1931 and 1932. The 1931 year class on the other hand was abundant in the estuarine catches only in the years 1933 and 1934. The 1933 year class had a similar history and dominated the estuarine catches during 1935 and 1936. Then followed year class 1935 which constituted over 90 per cent of the estuarine catches during 1937 and 1938 and which was prominent also in 1936 and 1939 so that this year class had features resembling the 1928 year class.

Table IV gives the age composition of the fish which spawned in February and March on Ballantrae Bank and along the south coast of Arran and there we find that precisely the same age classes which predominated in the estuarine shoals came into prominence in due course in the spawning shoals.

TABLE IV

BALLANTRAE BANK AND SOUTH COAST OF ARRAN
AGE COMPOSITION OF SPAWNERS FEBRUARY/MARCH, 1930-1939 (Percentages)

Year of Capture	Year Classes										
	1919-27	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937
1930	100·0	—									
1931	66·6	*33·4*									
1932	1·4	*97·4*	1·3								
1933	1·7	*85·2*	10·8	2·4							
1934	1·1	*25·3*	3·7	11·2	*58·8*						
1935	1·3	*14·4*	1·0	4·6	*76·5*	2·3					
1936	0·5	3·2	0·3	1·0	*30·0*	1·1	*63·9*				
1937	0·7	1·6	0·8	1·8	*16·6*	3·0	*73·9*	1·7			
1938	0·0	0·6	0·2	0·0	1·4	0·2	*23·4*	2·6	*71·7*		
1939						0·3	1·8	0·4	*95·0*	0·9	1·6

It has already been shown that the estuarine herring population is very predominantly spring spawning and there can be no doubt that the herring which mature within the estuary find their first spawning places on Ballantrae Bank and along the south coast of Arran. It is not so certain, however, that they continue to use these spawning grounds throughout the whole of their adult life.

Table I has already shown that extremely few spent fish appear in the estuarine catches at any season, which clearly implies that the spents desert the spawning grounds whenever spawning is completed. It is also clear from Table I that, while many of the spawners are derived from those which grew up and matured within the estuary, extremely few return for a further sojourn within the firth after spawning is completed. Knowledge of this fact makes it possible to determine the year to year progress in the sexual maturation of a year class. The youngest spawners are three years of age (although a few rare exceptions have been found maturing at two years), but the proportion of a year class that matures at three years can be very variable. The 1928 year class began to spawn in the spring of 1931 but it was not until February-March 1933 that the whole year class had completed its first spawning. After that date the number of the year class persisting within the estuary was quite insignificant. The 1931 year class made substantial contributions to the estuarine fishery in 1933 and 1934, i.e. in its second and third years, but became reduced to insignificant numbers in the estuarine population in 1935, and the 1933 year class showed precisely the same features in 1935 and 1936. In the case of both the 1931 and 1933 year classes it would appear that practically all the herring of these year classes had reached maturity at three years of age. The history of the 1935 year class, on the other hand, resembles that of the 1928 year class; some matured for the first time in their third year, some in their fourth year, but the year

class as a whole had not reached its first maturity until the age of 5 years, after which it virtually disappeared from the estuary.

While the mature component of each year class leaves the estuary on the completion of its first spawning it is quite clear from Table IV that that is not the whole story, for the various year classes, after their dispersal from the estuary, continue for a few years to reappear in the spawning shoals on Ballantrae Bank and along the south shore of Arran, although in rapidly decreasing numbers.

The indications are that the Clyde herring, after their first spawning in the outer reaches of the estuary, adopt a new habitat from which it is clear that some return to spawn again, but it is also almost certain that in their change to a new habitat some also adopt new spawning grounds, for it is hardly conceivable that the very abundant 1928 year class had been virtually eliminated by the spring of 1937, the numerous 1931 year class by the spring of 1938 and the 1933 year class by the spring of 1939. The problem now is to discover these new grounds, if indeed they exist. The examination of material obtained from the Cumberland coast in 1936 and from the Isle of Man in 1937 established that the mature or spent herring caught on these grounds in the autumn, as might have been expected, had the low number of vertebrae typical of autumn spawning herring in British waters and Hsüeh's work (1939) indeed confirms that such is the case.

The following age data refer to samples, which include fish at practically all stages of maturity from the Cumberland coast, the Isle of Man and the north east coast of Ireland.

TABLE V

AGE COMPOSITION (PERCENTAGES) OF HERRING SAMPLES CAUGHT IN THE NORTHERN PART OF IRISH SEA, 1936-38

Grounds	Year	Winter Rings 1	2	3	4	5	6	7-10	Fish Examined
Cumberland	1936	*12·9*	*46·3*	*28·8*	5·3	3·8	1·1	1·9	264
Isle of Man	1937	0·0	*77·1*	*10·8*	5·4	3·7	2·2	0·8	516
N.E. Ireland	1937	0·2	*70·8*	*13·3*	9·2	2·0	2·9	1·7	646
Isle of Man	1928	0·4	*36·7*	*51·5*	5·7	4·9	0·8	0·0	264

Table V shows that the herring shoals which maintain the summer and autumn fisheries in the neighbourhood of the Isle of Man and off N.E. Ireland consist very predominantly of young fish and this is in accordance with the records of Hsüeh (1939), Bowers (1955, 1956, 1957) and Smith (1957).

TABLE VI

COUNTS OF VERTEBRAE OF HERRING FROM NORTHERN PART OF IRISH SEA. ALL MATURITIES

Area	Year of Capture	No. of Winter Rings	54	55	56	57	58	59	Mean	No. of Fish
Cumberland	1936	2	—	3	43	67	6	—	56·64	119
Isle of Man	1937	,,	1	11	160	186	35	2	56·63	395
N.E. Ireland	,,	,,	—	7	143	171	22	—	56·61	343
Isle of Man	1938	,,	—	1	35	52	9	—	56·71	97
Cumberland	1936	3	—	3	39	31	3	—	56·45	76
Isle of Man	1937	,,	—	6	20	26	2	—	56·44	54
N.E. Ireland	,,	,,	—	2	38	30	2	—	56·44	72
Isle of Man	,,	,,	—	2	55	65	14	—	56·67	136

Counts were made of the vertebrae of the majority of the herring included in Table V and the results obtained for the dominant age classes are shown in Table VI.

Table VI shows that the fish with two winter rings on the scales undoubtedly included a few spring spawning fish, while those with three rings, with the probable exception of those of the last sample, had the characteristic counts of autumn spawning fish. The counts show that the material as a whole consisted predominantly of autumn spawning fish. There is thus no evidence from the age determinations and very little from the vertebrae counts to suggest that it is to this region that the adult herring of the Clyde resort after they have spawned and left the estuary and its neighbourhood. In fact one is tempted to infer from the scarcity of fish with more than three winter rings even in the spawning shoals that the herring of the North Irish Sea, which maintain the summer and autumn fisheries around the Isle of Man and its neighbourhood, also find another habitat after their first spawning is completed.

HERRING OF NORTH IRELAND AND BARRA HEAD

Another route for the dispersing spent herring from the Clyde spring spawning grounds is by the North Channel, between North Ireland and the Mull of Kintyre, which opens into the Atlantic. Herring fishing by Scottish vessels is now on a very small scale both on the N.W. coast of Ireland, where before the first World War a productive fishery was carried on from Buncrana in the late spring and early summer, and in the neighbourhood of Barra Head where a more or less productive fishery was carried on throughout the summer and autumn. In this region the herring provide an interesting contrast with the herring of the North Irish Sea in age and race composition. The following data were collected between 1934 and 1938 from grounds off North Donegal, Barra Head and Stanton Bank which lies between. To facilitate comparison with the Clyde herring the ages have been expressed as year classes and it is assumed, at least to begin with, that the fish belong to a spring spawning stock.

TABLE VII

AGE COMPOSITION OF HERRING SAMPLES FROM GROUNDS BETWEEN NORTH WEST IRELAND AND BARRA HEAD

Date of Samples	Year Classes (Percentages)										
	1923 to 1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	No. of Fish
				Off North Donegal							
April 1937	9·6	*5·1*	5·7	9·9	*44·9*	8·6	*15·3*	0·6	0·3	—	314
				Barra Head							
Sept. 1934	8·7	*6·2*	4·7	8·9	*56·9*	6·8	*7·8*	—	—	—	192
July 1935	22·5	*17·5*	6·7	9·2	*38·4*	4·1	*1·7*	—	—	—	120
Aug. 1937	5·5	*2·2*	3·8	4·3	*26·9*	6·7	*23·7*	2·0	*24·9*	—	1252
Aug. 1938	0·9	0·4	0·5	0·7	5·1	3·0	*8·1*	3·6	*76·7*	1·0	1300
				Stanton Bank							
July 1937	23·3	*14·1*	11·4	6·4	*22·4*	5·9	*12·8*	0·5	*3·2*	—	219

If analysis should establish that the data in Table VII were derived from spring spawning stock one notes that the prominent year classes in Table VII are precisely those that dominated the Clyde catches, namely year classes 1928, 1931, 1933 and 1935. We shall see later that age determinations by Storrow and Miss Cowan of samples obtained from off north west Ireland between 1933 and 1938 tell a similar story.

In Table VIII counts of vertebrae are given according to the year classes given in Table VII.

TABLE VIII

COUNTS OF VERTEBRAE OF HERRING FROM BETWEEN NORTH WEST IRELAND AND BARRA HEAD

Grounds	Date	55	56	57	58	59	Mean	No. of Fish
		Year class 1928						
N. Donegal	April 1937	—	3	11	2	—	56·94	16
		Year class 1931						
N. Donegal	April 1937	—	23	90	25	—	57·02	138
Stanton Bank	Aug. „	—	7	26	14	1	57·13	48
Barra Head	May-Aug. „	—	46	188	62	1	57·06	297
		Year class 1933						
N. Donegal	April 1937	—	5	32	11	—	57·13	48
Stanton Bank	Aug. „	—	8	17	4	—	56·86	29
Barra Head	May-Aug. „	3	75	156	54	1	56·91	289
		Year class 1935						
Stanton Bank	Aug. 1937	—	1	5	1	—	(57·0)	7
Barra Head	May.-Aug 1937	2	73	222	51	2	56·94	350

While some of the samples detailed in Table VIII may be regarded as statistically inadequate, the counts of vertebrae show that they consist very predominantly of spring spawning fish and this fact should be considered along with the recurrence of the same predominating year classes as had predominated in the Clyde.

According to Farran (1938) spawning takes place on the north coast of Donegal from January to March. The spent fish, which frequent grounds within range of the drifters until about June, then withdraw to the Klondyke grounds where they are exploited by trawlers from June until October.

There is no doubt whatsoever that the herring which spawn in the Clyde estuary leave it immediately after spawning is completed. There is no evidence that these emigrants from the Clyde become mixed to any recognisable extent with the herring which are exploited on the Manx grounds during summer and autumn, and so it would appear that the departure from the Clyde must be by the North Channel leading to grounds already inhabited by spring spawning herring, which have close affinities with the Clyde herring and which have a spawning ground on the north coast of Donegal. It seems almost inevitable that as a result of mixing with the spring spawners, which inhabit the grounds between North Ireland and Barra Head, some of the Clyde herring will share the Donegal spawning grounds.

TABLE IX

YEAR CLASSES IN HERRING SAMPLES FROM N.W. IRELAND 1933-1938

Date	Year Classes (Percentages)									No. of Fish
	1921-27	1928	1929	1930	1931	1932	1933	1934	1935	
1933 Apr.-May	59	*21*	9	10	*1*	—				478
1934 May-June	47	*20*	13	9	*11*	—				394
1935 Apr.-June	31	*20*	7	10	*31*	1	—			280
1936 Jan.-May	15	*15*	6	8	*40*	7	9	—		540
1937 Jan.-June	14	*13*	4	7	*38*	8	*11*	2	*3*	561
1938 May-June	1	2	2	3	*10*	8	*12*	7	*56*	390

Fortunately independent material is available in the Dove Marine Laboratory Reports from samples obtained off the north coast of Ireland, and examined by Storrow and Cowan (1933-40). The samples were caught in January and from April to June. The January samples included a predominance of herring maturing to spawn while the April-June samples included a majority of recovering spents, so that there is no doubt that the samples consisted predominantly of spring spawning fish and to that extent resemble the Clyde herring. The year classes represented in the samples are given in Table IX.

As in Table VII one notes in Table IX the prominence of the year classes 1928, 1931, 1935 and less prominently 1933, all of which had been conspicuous in the Clyde fishery. It will also be noted that the year classes 1928 and 1931 maintained some importance on the North Ireland grounds at least two years after they had ceased to be important on the Clyde grounds; see Tables III and IV. In short it will be seen from Tables VII and IX that the region between North Ireland and Barra Head supports a population of spring spawning herring containing an appreciably higher proportion of the older year classes than the herring population which frequents the Clyde estuary during summer and the spawning grounds in the outer Clyde estuary in February and March. There is thus some justification for believing that it is to the region between North Ireland and Barra Head that the Clyde herring resort after spawning.

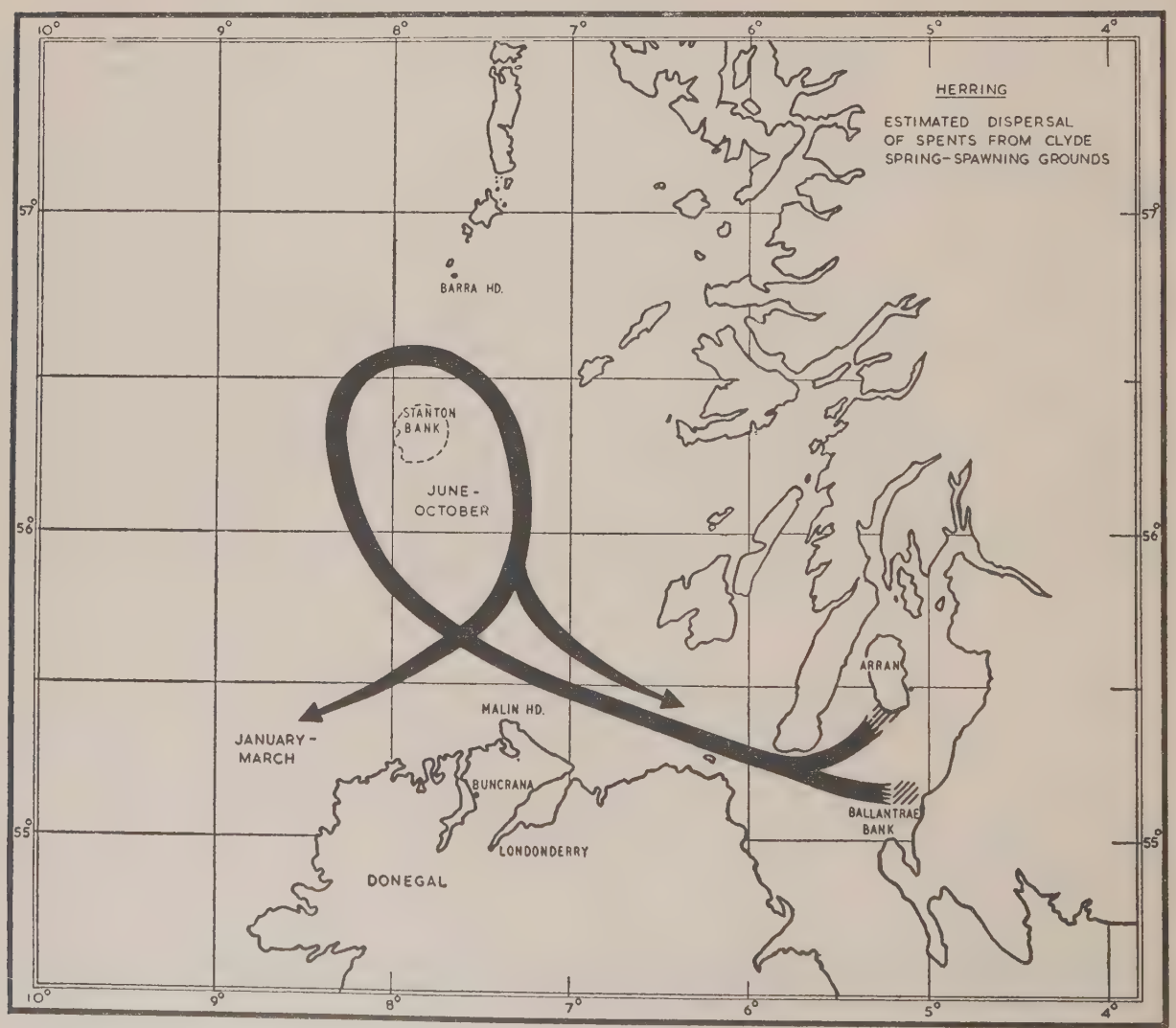

Fig. 3

It seems possible that they may extend their movements even to St. Kilda or the Flannan Islands, where in the spring shoals of large herring concentrate to spawn, similar to those which spawn on the coast of Donegal and which in summer inhabit the grounds between North Ireland and Barra Head. An extension of the somewhat limited tagging programme undertaken on Ballantrae Bank and near the south coast of Arran should ultimately yield very useful results.

FLUCTUATIONS IN HERRING BROOD STRENGTH

The Clyde herring fishery in the period 1930-1939 was relatively successful except for the year 1936, when fishing was much interrupted by bad weather. The success in terms of catch was due to a succession of good year classes. The contribution to the fishery by each year class in the period under review is given in Table X which gives the annual landings in tons between 1929 and 1938. In accordance with the biological calendar of the herring the year begins on 1st April.

TABLE X

CONTRIBUTION (TONS) TO CLYDE HERRING FISHERY BY DIFFERENT YEAR CLASSES FOR EACH YEAR COMMENCING 1st APRIL: 1929-1938

Year of Landing	Year Classes											
	1920 1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	Totals
1929	1,431	*2,203*	—									3,634
1930	2,780	*15,153*	167	—								18,100
1931	603	*28,474*	6,066	217	—							35,360
1932	196	*20,414*	3,171	4,280	*1,024*	—	—					29,085
1933	40	*1,391*	258	1,369	*22,751*	87	—					25,896
1934	34	*266*	95	487	*11,487*	876	*115*	—				13,360
1935	10	*80*	10	25	*867*	101	*16,383*	55	—			17,531
1936	—	*1*	—	1	*38*	20	*2,384*	396	*775*	—		3,615
1937		*12*	4	—	*29*	4	*172*	53	*12,441*	—	—	12,715
1938						27	*348*	137	*20,919*	520	103	22,054
	5,094	67,994	9,771	6,379	36,196	1,115	19,402	641	34,135	520	103	181,350

The outstanding year class was that produced in the spring of 1928, which during its sojourn in the neighbourhood of the Clyde contributed almost 68,000 tons to the catch or about twice as much as the next best year class produced in 1931, about sixty times more than the 1932 year class and about a hundred times more than the very unsuccessful 1934 year class. It is recognised that the contribution to the catch by the 1934 year class is based on only 4 years' fishing but to judge by the history of the other year classes it would already have nearly completed its contribution, which is unlikely to have exceeded 700 tons.

Catch figures cannot be accepted always as an index of the abundance of a herring stock, because, for example, in this country the demand for herring has not always been unlimited and between the World wars over-supply was not an unusual feature of the herring fishery. During 1930 and 1931, when the Clyde catch was based mainly on the 1928 year class, considerable dumping of catches took place and economic conditions imposed severe restrictions on the fishery. If indeed unrestricted fishing had been possible in 1930 and 1931 the catch in those years might easily have been doubled. The Clyde fishing fleet does not confine its operations to the Clyde. It may fish in the waters around the Isle of Man or in the sea lochs along the west coast of Scotland, and the whole, or part of it, will give attention to the region where prospects are best. The vessels work in a partnership of two or three but in the landing of the catch the vessels going to port may be one, two or three according to the size of the catch. It is thus almost impossible to obtain a true measure of the effort expended in securing the catch and accordingly a true measure of the strength of the fish stock based on catch and effort. Nevertheless there is no doubt whatsoever that the ratio of the brood strengths of the 1928 and 1934 year classes greatly exceeded the catch ratios of 100:1 indicated in Table X.

CLYDE HERRING FISHERY.

TONS OF HERRING PROVIDED BY FOUR PROMINENT YEAR CLASSES.

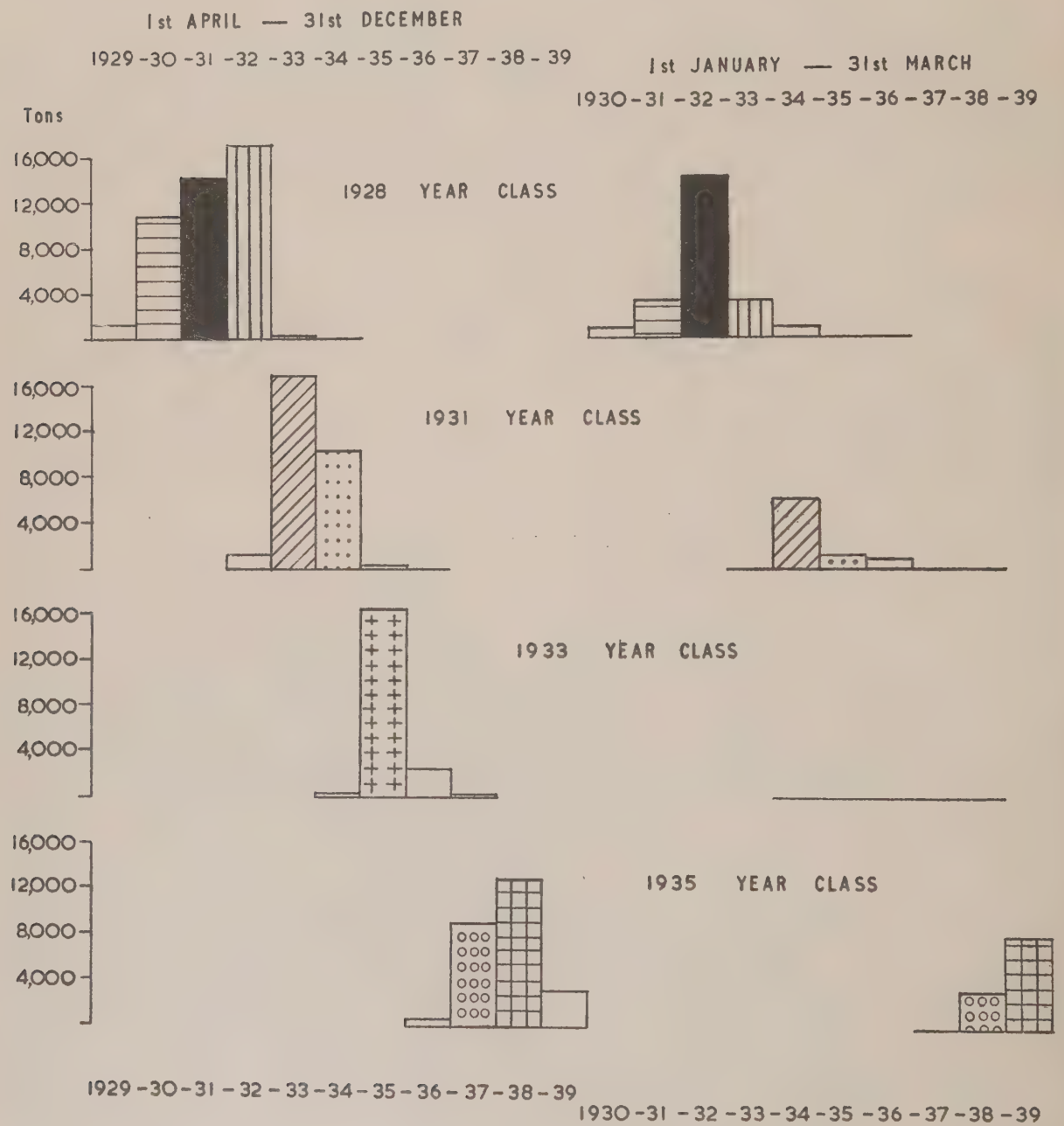

Fig. 4

Table X shows that there would appear to be no correlation between the number of spawners and the number of their progeny which survive to contribute to the fishery. Spawning in the Clyde area takes place mainly in February and March. The year of landing in the table is the year from 1st April to 31st March, which is the true biological year of the herring. A year class, however, is given in its true calendar year so that in our table the year class 1931 is the progeny of those adults which contributed to the catch of 1930, i.e. extending from 1st April to 31st March 1931.

It will be seen that the numerous 1931 year class was derived to a large extent from the numerous 1928 year class, some of which spawned for the first time in the spring of 1931, but the rather poor 1932 year class was derived also from the abundant 1928 year class at a time when the number of its spawners was considerably higher than in 1931. Then the 1934 year class, the poorest year class represented in Table X, took its origin mainly from the abundant 1931 year class, the majority of which, as we have already seen, spawned in the spring of 1934. There is thus no regular correspondence between numbers of spawners and numbers of their offspring.

Little is known about the causes governing the fluctuations in brood survival. One can imagine the possibility of herring eggs laid on a shallow bank, such as Ballantrae Bank, being silted up during periods of storm. Lea (1930) and Runnström (1941) established that on the spawning grounds near the south-west coast of Norway sometimes layers of eggs may be superimposed on each other to such an extent that great numbers of the underlying eggs are suffocated and die. Hjort (1926) regarded that a critical stage of a brood was reached when the yolk-sac was absorbed and when the baby fish had to find its appropriate baby food amongst the plankton, and it is possible that the larvae at the mercy of the vagaries of the ocean currents may be drifted to areas where conditions, at least temporarily, may be unfavourable for their survival. The factors affecting survival are probably many and complex. Nevertheless it is interesting to note from the evidence at our disposal that the years which produced successful herring broods in the Clyde area also produced successful broods on the grounds off the north-west of Ireland so that it would appear that in those years the favourable conditions were not local but were quite widespread.

It is quite clear that in the Clyde or anywhere else the success or failure of a brood is determined long before it becomes subject to exploitations by man. This fact, however, should not be taken to imply that fish stocks, whether of herring or any other species, cannot be impaired by wasteful and indiscriminate fishing.

SUMMARY

From the results of the analysis of herring from the Clyde estuary it has been established that the O group stage (finger-length size and slightly larger) may include progeny from an autumn spawning stock, probably Isle of Man stock, and spring spawning stock derived from the spawning grounds of Ballantrae Bank and the south coast of Arran. The Clyde herring first become subject to capture by ring nets when they are from $1\frac{1}{2}$ to 2 years old, i.e. in the autumn and winter of their second year when they measure from about $7\frac{1}{2}$ to $8\frac{1}{2}$ inches in length. Herring at this stage in the Clyde have been found to consist predominantly, if not exclusively, of spring spawning fish and they may be expected to remain within the estuary until their first spawning is completed. Some spawn at the completion of their third year, some at the end of their fourth year and practically all have spawned at least once at the end of their fifth year. In some cases practically the whole of a year class may complete its first spawning at the end of its third year. In every case the fish which spawn, be it in their third, fourth or fifth years, leave the estuary after spawning by the North Channel between Ireland and the Mull of Kintyre to inhabit a region which, it is believed, lies between North Ireland and Barra Head, from which some return at the appropriate time to spawn once again on the Clyde spawning grounds, but where others presumably find a new spawning ground near the north-west coast of Donegal.

By the completion of spawning, usually about the end of March, the estuarine stock of herring becomes reduced by the dispersal of those herrings which matured and spawned and for a time, at least, the fishery becomes dependent again almost exclusively on immature herring. There is, as a rule, little

prospect of any appreciable addition to the fishable stock until the late summer or autumn, when the eighteen-month old "halflins" have become large enough to be retained by the meshes of the ring net. Undoubtedly the most reliable prospects for the Clyde fishery are found when a good crop of "halflins" makes its appearance during the course of the autumn, because they will undoubtedly persist in the estuary and be available for the fishery for at least fifteen to eighteen months and those which do not spawn at the end of that time will continue to contribute to the estuarine catch for still another year.

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